Aeolian Processes and Landforms

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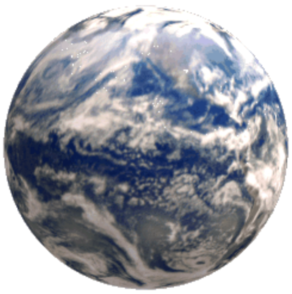
Abstract



I will present an overview of Aeolian processes and landforms on Mars. The overview will consist of two components. Component one is an overview of Aeolian processes and landforms on Earth and Mars, where the two planetary bodies are shown in Figures 1a and 1b respectively The second part of this paper will consist of image comparisons using satellite and MOC (Mars Orbiter Camera) images.

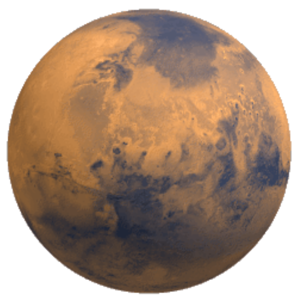


Figure 1a **Figure 1b**

Introduction

Understanding the aeolian activity on the planet Mars and other planets begins with the study and knowledge of similar processes on Earth. Therefore, I will discuss the following: wind, particle entrainment and landforms found in the aeolian environment. This discussion will lead into my later discussion of the Martian sand seas and sand dunes. See Table 1 for a glossary of the terms used throughout this paper.

In aeolian processes, wind transports and deposits particles of sediment. Aeolian features form in areas where wind is the primary source of erosion. The particles deposited are of sand, silt and clay size (see Table 2). The particles are entrained in by one of four processes. **Creep** is when a particle rolls or slides across the surface. **Lift** is when a particle rises off the surface due to the Bernoulli effect, the same mechanism which causes aircraft to rise. If the airflow is turbulent, larger particles are trajected by a process known as **saltation**. Finally, **impact** transport occurs which one particle strikes another causing the second particle to move.

Erosional Landforms

Wind eroded landforms are rarely preserved on the surface of the Earth except in arid regions. Elsewhere, moving water erases the Aeolian landforms. There are several types of landforms associated with erosion: lag deposits, ventrifacts, yardangs and pans. See Table 3 for a description of each type. Large basins are complex and there is often one or more non-aeolian processes work. These non-aeolian processes include tectonics, glacial and alluvial forces. (See Table 1)

Depositional Landforms

Deposition is the laying down of sediment transported by wind, water or ice. A depositional environment occurs when there is a reduction in velocity in the transport medium whether it’s wind, water or ice. Depositional landforms develop in a wave like pattern mimicking the fluid flow. The three types of depositional landforms are **ripples, dunes and mega dunes**. These features are discussed in Table 3 which includes a break down of dunes by subtype.

Dunes

Dunes start off as a stationary body of sand behind a topographical obstacle. Once a dune reaches a certain height, migration begins. Migration is nothing more than the erosion and deposition of sand from the windward to the leeward side of the dune as shown in Figure 2 where the wind pushes grains up the backslope side of the dune. Accumulation occurs behind the crest. When the slope reaches 30-34 degrees it will fail. As a result, sand is transported down slope on the slip face side of the dune. The cycle is repeated and the dune slowly changes location, moving in the direction the wind is blowing until there is a change in wind pattern. Dunes are classified by their shape and environment and include **barchan**, **transverse**, **star** and **dome**. Each type is described in Table 3.

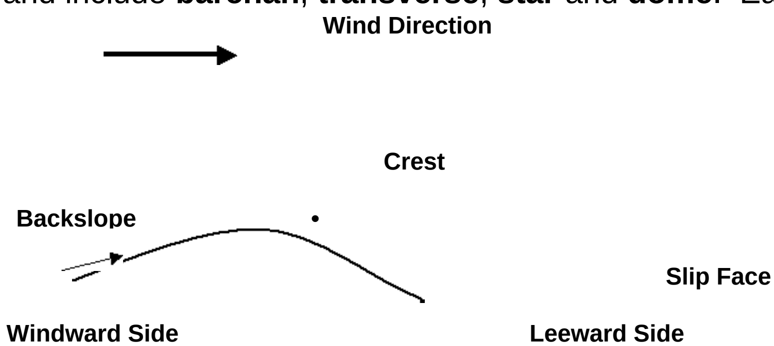


Figure 2

Martian Aeolian Activity

The idea of wind on Mars is not a new one. Aeolian activity on Mars was first mentioned in 1909 by E.M. Antoniadi but was not detected by others at the time. Antoniadi observed yellow clouds when Mars was closest to the sun. Indisputable confirmation of wind activity on Mars occurred in 1971 when NASA's Mariner 9 went into orbit around Mars but was prevented from imagining the surface for two months because of the presence of planetary wide dust storms.

A number of global factors influence planetary landform development such as the planet's mass, distance from the sun, chemical composition, atmosphere, surface temperature and surface gravity. For example, the mass of a planet determines both the surface gravity of the planet and the density of the atmosphere. This along with the surface temperature in turn influences the speed and strength of surface winds which in turn influence the Aeolian rate of erosion. On Mars, the lower mass of the planet and lower atmospheric density and pressure means that saltating grains on Mars have 20 times the velocity of their counterparts on Earth. This means greater erosion rates per particle on Mars. Table 4 compares global variables for the two planets.

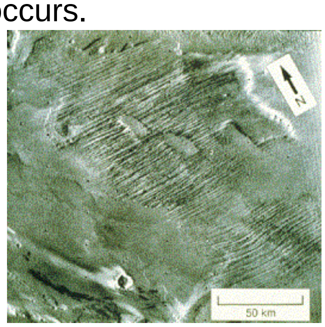
Aeolian Landform Comparisons

There are many types of landforms on the Martian surface: volcanic, tectonic and Aeolian. Recent NASA missions have provided strong evidence of alluvial activity as well. The Aeolian landforms on Mars are similar to their Earth counterparts and so a comparison is in order.

Figure 3a is a set of yardangs located on Earth in the Lut Basin of Iran. These yardangs are 80 m high and several meters apart. Figure 3b is a set of yardangs on Mars which are 50 km long and 1 km wide with ridge heights of 200 m. The Martian yardangs are in the early stage of development as evidenced by the lack of a streamlined shape to the ridges. While the Martian sediment is the same size as the sediment found in the Lut Basin its chemical composition is different.

Figure 4a is an aerial photograph from the Empty Quarter in Saudi Arabia of an active dune field which contains barchan, linear and star dunes. The dunes are about 100 m tall and 2.5 km wide and spaced about 2.6 km apart. Figure 4b is an active dune field in the Martian crater Proctor. The image is a combined MOC (Mars Orbiter Camera) and a Mariner 9 image. The similarities in appearance between the terrestrial and Martian dune fields is striking.

Figure 5a is an aerial photograph of barchan dunes located in the Salton Sea, California. Figure 5b is a MOC image of barchan dunes in the Charsma Boreale region on Mars. Even though the images are taken at different elevations notice the similarities in the shape and spacing of the dunes. The crescent shape is characteristic of barchan dunes. The wind direction is determined by the orientation of the dune. The shape and orientation of the dunes in Figure 5a indicates a wind from the North West. Figure 5b indicates a wind from the North. The landforms on Mars are larger than their Earth counter as result of the lower surface gravity on Mars where the dunes can reach a greater height before slope failure occurs.



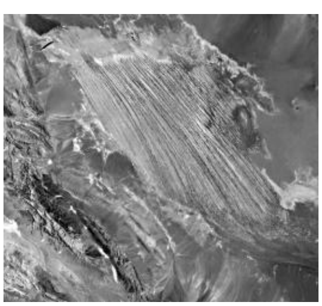
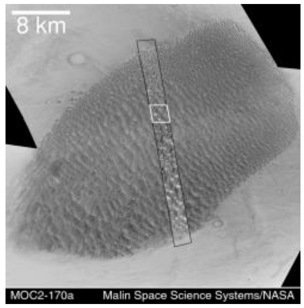


Figure 3a

Figure 3b



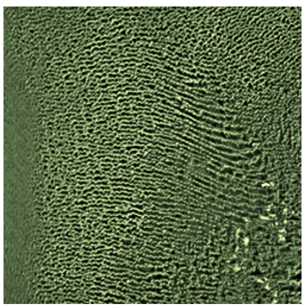


Figure 4a

Figure 4b

Figure 5a

Figure 5b

Summary

A number of pieces are needed to put together the Martian geological puzzle. Understanding aeolian activity on Mars begins with studying similar processes and landforms on Earth where one can observe the features at close range. As technology advances, the image quality and resolution will improve and reveal more details about the Martian surface. Future missions will send more rovers and other surface equipment to help better understand the local and global variables which influence the formation of these landforms.

Acknowledgments

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Table 1
Glossary

Aeolian	Involving wind.
Alluvial	Involving a stream or river.
Detrital	Sedimentary rocks that breaks off other rock through chemical and physical weathering.
Evaporites	Sedimentary rocks that precipitate out of water. Examples halite(salt)and gypsum.
Faceted	Having a smooth surface.

Glacial	Involving a glacier
Granite	Medium to coarse grained igneous rock that is rich in quartz and potassium feldspar. Derived from iron rich magma.
Quartzite	Metamorphic rock rich in quartz created by the recrystallization of sand stone.
Sand dune	A hill or ridge of aeolian sand deposits with a minimum height of less than one meter and a maximum height of about 50 meters
Tectonics	Structures associated with deformation and faulting of the crust.

Table 2

Maximum Particle Size by Class

Size Class	**Size in millimeters**
Boulder	>64
Cobble	64
Pebble	16
Granule	2.0
Very Coarse Sand	1.0
Coarse Sand	0.5
Medium Sand	0.25
Fine Sand	0.125
Very Fine Sand	0.0625
Coarse Silt	0.0156
Fine Silt	0.0078
Clay	0.0039

Table 3

Aeolian Landforms

Process of Formation	**Type**	**Description**	**Wind Direction**
Erosion	Lag deposits	Layers of courser particles overlaying finer particles.	
	Ventrifacts	Cobbles and pebbles with smooth sides due to wind abrasion.	
	Yardangs	Streamlined parallel ridge usually less than 10 m high and 100m or more in length aligned with and typically tapering away from the direction of the prevailing wind.	
	Pan	Large broad basins.	
Deposition	Ripples	Range in height from 1 mm to 500 mm with wavelengths from 0.01 m to 5 m.	One

	Barchan Dunes	Crescent shape dunes form whose long axis is transverse to dominant wind direction. Barchan form where the sand supply is limited.	One
	Transverse Dunes	Asymmetrical ridge form at right angles to the wind direction. Transverse form when sand supply is abundant and winds are weak.	One
	Star Dune	Central peak with three or more arms. Each arm corresponds to a wind direction. Star dunes do not migrate but grow vertically.	Three or more
	Dome Dune	Circular or elliptical mound.	None

Table 4
Planetary Properties

Property	Mars	Earth
Mean Distance from Sun	142 Million Mi 228 Million Km	93 Million Mi 150 Million Mi
Known Mass (Earth =1)	0.107	1.000
Diameter	4222 Mi 6794 Km	7926 Mi 12756 Km
Tilt of Equator to Orbit (Degrees)	25.19	23.45
Length of Year (Earth Days)	686.97 Days	365.24 Days
Rotational Period (Day)	24.6 Hrs	23.9 Hrs
Surface Gravity (Earth =1)	0.377	1.000
Atmosphere Main Components	Carbon Dioxide	Nitrogen Oxygen
Atmosphere Minor Components	Noble Gases Nitrogen	Carbon Dioxide Noble Gases
Temperature Range (Celsius) Degrees	-161 to 0	-89 to 57
Pressure at Surface (Millibars)	6	1000